The need for multi-level thinking in meeting the 2050 target reduction in CO_2 emissions in domestic dwellings

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Introduction

In October 2008, the UK government announced the goal of an 80% reduction in CO_2 emissions relative to 1990 levels. This figure relates to the entire UK emissions, not only emissions from the built environment. However, since between 66% and 80% of the existing housing stock will still be standing in 2050, the emissions from the existing housing stock will have to reduce by a similar amount. There are currently approximately 25 million dwellings in the UK [1]. These were responsible for emissions of 41.7 MtC (metric tonnes of carbon) in 2004. This represented 27% of the total UK carbon emissions that year. The UK has the oldest building stock in the developed world [2]. This paper will examine two broad topics in this wider-reaching field: reducing emissions from electricity production and reducing electricity use within the UK housing stock. It specifically focuses on the barriers that could hinder reaching the target, and evaluates what measures need to maintained or added.

The use of micro-generation in domestic dwellings is, and increasingly will be, an important part of the country's energy strategy. However, there are still major advances needed to make this a practical solution for many of the UK's dwellings and their occupant's lifestyle. While many studies have shown that it is certainly theoretically possible to meet, and even exceed, the 80% reduction in emissions by 2050, fewer have looked at how these will be realistically achieved, and what effects these will have on our existing built environment. The wider sphere of emissions such as electricity production at a national energy production level and at the single dwelling micro-generation level, and their relation to each other are discussed. The paper combines existing government data on planned energy saving measures and proposed possible pathways and the barriers which need to be breached in order to meet the reduction needed.

Energy

The UK will need to implement radical changes to the current energy supply situation. Energy use in the residential sector is rising more quickly than in the UK economy as a whole. In 2004, the DTI reported that the total UK energy demand had grown by 7.3% between 1990 and 2003, but residential energy consumption grew by 17.5% over the same period [1]. Energy use per household has changed little since 1970, but due to increasing household numbers, overall energy use in the residential sector has increased by 32%. Per dwelling, the energy saving effect of reduced heat losses has been offset by increases in demand for electricity use in lighting, appliances and the increasing number of electricity hungry devices in the home [1]. While the actual energy consumption per dwelling in the UK has dropped from 83.5 GJ in 1970 to 73.1 GJ 2006, the average consumption of energy by lighting and appliances has increased from 6.0GJ in 1970 to 10.6GJ in 2006 [3].

An important part of sustainability is not only carbon counting but also political sustainability. Richard Branson is quoted as saying 'The next five years will see us face another crunch – the oil crunch. This time, we do have the chance to prepare. The challenge is to use that time well' [4]. Any disruption to either the electricity or overall energy supply can have serious long tern political and economic stability of the entire country and being dependant on fuels from politically unstable or hostile countries or areas of the world can lead to serious economic and political problems. An example of this is the gas supply from Russia to its neighbouring countries and the rest of the EU. A country can literally be held to ransom if they become over-dependent on foreign sources of fuel. For this reason it is recommended that gas powered power stations, although the most efficient of the fossil fuelled power stations, must also be decommissioned and not replaced with the same. This is also to help preserve our non-renewable supply of gas. Instead of providing fuel for power stations, gas will be used for high-efficiency water and space heating in dwellings and other buildings as well as localised community and micro CHP systems. This, even with the increase in house numbers and the possible increase of gas uptake in existing dwellings and buildings, as an efficient and lower carbon output of an existing heating system (such as coal or oil or electricity) would help preserve the existing natural gas stocks and hopefully extend the life of known gas resources and reducing the need within the foreseeable future to seek new gas supplies in possibly environmentally sensitive areas such as the Polar regions.

Electricity Use and Reduction

The first and most vital step to reducing emissions and increasing the sustainable performances in existing housing is to reverse the rising trend of electricity consumption from the existing housing stock. This paper will focus on two specific areas of domestic electricity use, lighting and appliances.

Lighting

Lighting represents one of the best opportunities for major reductions in energy consumption and carbon emissions. Nearly a quarter of all electricity used in the average home is used for artificial lighting [5]. The opportunities for reducing lighting energy consumption are significant. Government policy over the last few years has developed a strategy for every home to have at least one low-energy compact fluorescent lamp (CFL). Around 40 million were distributed through this incentive between 2000 and 2004[5]. Although compact fluorescent lamps are one of the most popular energy efficient alternatives to tungsten filament lamps, the public acceptance of CFL has not been whole hearted. Innovations in lamp technology have resulted in an increased use of LED replacement lamps, available to fit existing traditional light fittings. These are relatively new to the market and remain relatively untested. However, they have almost 10 times the efficiency of a standard GLS lamp. The LED is seen by most as the future of artificial lighting as they have an extremely long life and are very energy efficient. Although commercially available now, they have yet to make a significant dent in the market compared with CFL. The savings from using low energy lamps over traditional lamps can be considerable and has a very short payback period. In a typical existing UK dwelling, the electricity saving would be in excess of 60% over conventional bulbs.

Appliances

Domestic energy usage on appliances has doubled in the last 30 years [6]. While the energy efficiency of our homes and the products we use within them, has improved by around 2% per year since 1970, our insatiable appetite for energy consuming appliances and consumer electronics has far outstripped this improvement. Between 1972 and 2002, electricity consumed by household domestic appliances in the UK doubled and is anticipated to rise by a further 12% by 2010 [6]. The increase in the number of consumer electronics in the average home has been a major contributor to the rise in domestic energy consumption [6]. Reversing this trend is critical if we are to meet the 80% reduction in emissions by 2050.

Appliance ownership has been on the rise throughout the 20th Century and this appears set to continue into the future [1]. One of the biggest areas of growth has been in labour saving devices and personal/home entertainment systems [6]. The 'digital revolution' that started in the 80's continues, and has resulted in a multitude of new appliances on the market. This would have been hard to predict 30 or 40 years ago [1]. The shift towards reducing and reversing demand is going to require multiple methods. Many of the improvements could be achieved via the improvement in technology alone and this does not have to take into account the many possible behavioural shifts that could occur in adopting the technologies [1]. These include such features as lowering energy consumption when in use and when on standby and the deployment of smart energy management systems.

Appliance ownership has increased with the trend towards multiple appliance ownership, for example, additional televisions in bedrooms. Ownership levels have now reached saturation in some areas such as cold appliances, but are still growing in others areas, particularly in the consumer electronics sector. The overall trend is still moving towards an increasing number of appliances in each home. The Growth of digital and computer products in the so called ‘Digital revolution’ of the last 10-20 year begs the question of how many more such ‘revolutions’ are likely to occur between now and 2050. Whilst it is difficult to predict what will happen, it is clear that if consumption in appliances is to decrease, then the general ethos has to move away from accumulating more and more appliances. This would require a significant shift in peoples’ attitudes and the way in which manufacturers and retailers drive the newer trends [1].

The possibility for appliance improvement is increased by their quick turnover. A cold appliance on average is replaced every 14-18 years. Therefore, by 2050, all appliances in a dwelling should have been replaced at least twice, providing ample opportunity for the introduction of more efficient technologies. Conversely, a new technology that is inadvertently inefficient can be rapidly accepted by the market, with negative impacts lasting for years, for example, large-screen plasma TVs which consume 350 W in the on-mode, compared to 75 W for the average cathode ray tube (CRT) TV [1]. However, again, this item can relatively quickly be replaced with a lower energy alternative, such as a LCD TV which has much lower energy consumption than both CRT and Plasma TV.

The population is increasing and the rise in household numbers is a strong driver towards higher levels of total consumption, and this is a trend that is virtually impossible to alter. This makes it all the more important to secure reductions in energy consumption per appliance and therefore each dwelling to compensate [1]. While the improvements in energy consumption and efficiency are technologically based they are usually brought about either through legislation or a secondary benefit of another need or feature, For example, the increase energy efficiency of a notebook computer to extend battery life.

For the past 10 years, technological improvements in energy efficiency have been the main focus of product policy at the European level, using a market transformation approach [1]. This is a set of policies that work together to bring about a shift in the market towards more efficient appliances. Whilst not the only factor behind reducing energy consumption, technological improvements have the advantage that savings are guaranteed and irreversible, unlike behavioural changes [1]. Most household appliances are now supplied with an energy performance certificate which indicates the efficiency of the product in relation to size and/or function. The efficiency in relation to size is a major criticism of the energy certificate. Whilst an emphasis on energy efficiency is important, without equal focus on energy use, this will not necessarily lead to reduced energy consumption, as portrayed by the appliance energy label. This is because the label is based on relative values, such as kWh/litre[1]. This actually encourages manufacturers to produce larger models since this makes it easier to attain an A-rating in a larger appliance. A smaller appliance consuming the same amount of energy overall would have a higher kWh/litre value and would therefore receive a lower rating. If the aim is to reduce consumption, then the principle of smaller, not larger, is needed, particularly given the trend towards smaller households and dwelling sizes. Using absolute consumption as the basis for the energy label would help to encourage energy conservation and give the consumer a better idea of the energy use of the appliance.

The setting of minimum standard can have a serious impact on the energy consumption of appliances. For example, the 1999 minimum standards for cold appliances in the UK was a 15% improvement in energy efficiency of the average appliance sold over 15 months (January 1999 - March 2000). This was also accompanied by a 14% drop in average purchase price [1]. This benefitted both the environment through lower energy consumption and the consumer through lower purchase price and lower energy bills. The application of minimum standards on all household appliance and consumer electronics could have similar impacts, further offsetting the increase in ownership levels. However, as with the energy performance labelling scheme, there has been criticism of the low/weak levels of the minimum standard imposed and some appliances have no minimum standards at all [1]. By applying minimum standards to all appliances and raising the existing standards, a saving similar to cold appliances could be made for all consumer appliances and electronics.

Future Electricity Consumption

The predicted growth in such areas as electric cars and the move towards increasingly electrified public transportation could very well increase the demand on the UK's electricity supply. As the 'Digital Revolution' saw a huge rise in demand of electricity for the domestic market. The perceived growth in electric vehicles could again see a huge increase again in domestic electricity needs. This fact highlights the need for concerted effort by all groups to improve efficiency of current electricity uses and matched with an predicted growth in dwelling numbers highlights the need for decreasing the amount of electricity used by the average existing dwelling.

Electricity Generation

While dealing with electricity generation and its related environmental credentials some published findings concentrate on the working methods of the home and local generation. One of the first barriers to overcome is the disparity between the time of day necessary for usable energy production (heat and electricity) in micro-generation and the time of day of consumption and final use. While hot water can be relatively efficiently and effectively stored in well insulated hot water tanks within a typical dwelling, there is no means of cheap and efficient storage for electricity produced in the home. while battery storage is available, it remains inefficient in terms of electrical energy lost and at other end of the spectrum fuel cell storage is very efficient but very expensive. The current solution for this is feed in tariffs, which is where electricity, that is produced via micro-generation and not used at the source, is sold back to the national grid energy suppliers. This current system highlights the need for a national grid electricity supply network. However, while local and micro generation is an important part of any future energy plan, most existing dwellings still rely on the centrally generated national grid system for their electrical power. It is essential to consider this as an important part of this country's future energy strategy.

There has been an increased awareness of where we source our fuel and the political and environmental problems related to that. Increasingly fossil fuels such as oil and natural gas (and to a lesser extent coal) come from areas and countries of the world that are either politically unstable or poor diplomatic and political relations. This has led some countries to be dependent on others for fuel supply. Over the last 30 years, the UK has reduced significantly the amount of national mining and localised fuel sourcing through the closure of coal mines, and has become increasingly dependent on foreign fuel imports for its energy and electricity production. While North Sea oil and gas still remains a viable source of fuel for this generation it is widely accepted that this source of fuel will not be able to provide the majority of the country's energy needs for the future.

Different forms of electricity production produce different amounts of CO_2 emissions. This applies to both National Grid and local electricity production. Carbon emissions are not the only environmental factor that needs to be considered. There is no such thing as zero carbon electricity production. All technologies produce or emit carbon and pollutants in some way. This is either in the manufacturing of the technology, the supply of the fuel or in its construction. However, many technologies can be considered to be zero and low carbon technology in their running and day-to-day use and as long as these embodied carbon costs are accounted for the term zero and low carbon technologies can be considered appropriate. The major concern is the impact of electricity production on climate change and pollution [7].

Future Electricity Supply

Since the majority of dwellings rely on the national grid for some or all of their electricity needs, it could be concluded that making the national electricity grid a low/zero carbon source of power is vitally important. It is worth bearing in mind that the National Grid not only serves dwellings but serves the entire built environment from offices to industry to street lighting to all of the basic utilities such as water purification and sewage treatment. The current (2008) grid electricity supply on average produces around 467 Tonnes CO_2/GWh [8]. To create a low carbon national electricity supply one of the first steps is the reduction of highly polluting oil, coal and gas fired power stations. Coal fired power stations are the most polluting of all the major methods of electricity production. The next step is to stop the commissioning or re-commissioning of new coal fired power stations. For the existing stock of coal powered power stations either decommissioning or the fitting of a carbon capture schemes must be carried out as soon as feasible. The replacement of these power stations with either nuclear or other low/zero carbon electricity production methods such as wind, hydro and other renewable energy sources must be a priority for the government if the 80% reduction in carbon emissions is to be met.

Nuclear power electricity generation, even with all of its obvious drawbacks and risks is now being accepted as one of the major contributors to meeting the needs of a lower carbon society. Even past critics of the nuclear power programme have admitted that there is no other way for us to meet the country's needs for electricity in the short term than by using nuclear power to some extent. The main advantage of using nuclear power is that its fuel does not release CO_2 during it production of electricity. However, the risk of radioactive waste and radioactivity leaking from the power station remains a serious environmental worry and the security of known fuel supplies is debatable. Nuclear power remains an important part of the government's low carbon energy strategy. The government is aiming for around 20% of electricity produced in this country by 2050 to be produced by nuclear power. Most of the proposed sites of the new nuclear power stations are near or on existing sites of nuclear power stations.

One of the major environmental assets of this country is its physical geography as an island, as we have huge potential for offshore and onshore wind farms as well as Hydro electricity production. These will be utilised to maximum effect in both policies. Although micro wind generation is having a mixed response, on a large scale wind power can produce significant amounts of sustainable and renewable electricity [9]. The possible environmental problems of wind farming such as the effect on wildlife have been dismissed by the RSPB. The main barrier of large-scale wind farms is the visual impact to the environment. There is a theoretical possibility of producing the whole country's needs solely from wind power [9]. However, the logistics of connection, supply and maintenance, as well as the visual impact, will make this highly unlikely and in reality impossible. The DTI predicts that by using shallower offshore sites (in water less than 30 m deep that are within British territorial waters) around 100 TW hours per year would be commercially viable by around 2025. The DTI also expects around 8 TW of onshore wind farms to be installed by around 2025[10]. Currently there are around 27,000 sq.Km of offshore wind farms producing 32 GW of electricity either in use in construction or been approved through the planning process around the UK [11]. Although hydropower in this country is less developed and less widely used than wind, as an island, we have significant potential to produce electricity by wave power. The DTI states that we have the technical potential to produce over 600 TW hours of electricity per year and about a fifth of this will be commercially viable by about 2025 [10]. Again hydropower will form an important part of the future electricity production for the National Grid by 2050.The advantage of wave and tidal power energy production is that it can often be integrated into other civil engineering projects such as barrages, tidal barriers, dams and bridges and can be retrofitted into existing civil engineering projects.

Conclusion

There is an urgent need for various changes in the way existing dwellings use electricity and the way the electricity is produced. These changes have to be made at various levels and scale from the individual dwelling reducing its electricity consumption to a complete change in the way the national grid is supplied. The future of electricity supply is most probably going to comprise both nationally and locally generated power, and until a solution to cheap, efficient home storage of electricity is resolved, feed in tariffs remain the most viable way of overcoming the disparity between production time usage in the home.

The future national grid electricity supply has to move towards an increasingly renewable supply, not only to reduce emissions from production but also to secure politically and economically stable electricity supply. By 2050 the electricity supply will have moved away from a fossil fuel dominated supply to a nuclear, wind and hydro powered electricity supply. The

UK's physical geography as an island has huge potential for offshore and onshore wind farms, as well as hydro, wave and tidal electricity production. Any future supply has to be flexible enough to cope with any future increase in demand as our electric transportation revolution and the population growth demands.

The application of minimum standards to all appliances, the raising of existing standards and the inclusion of energy consumption data on energy performance certificates would help consumers to make better informed decisions when purchasing new goods. The inclusion of actual energy consumption on energy performance certificates would hopefully encourage manufacturers to design and supply smaller, more efficient appliances. The reversal of the rising trend of electricity consumption from the existing housing stock needs to become a priority if the radical reduction in emission from the existing housing stock is to be met by 2050.

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